DEVELOPMENT OF A RESIN TREATED COTTON THREAD
FOR THE DURABLE PRESS PROCESS

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DEVELOPMENT OF A RESIN TREATED COTTON THREAD

FOR THE DURABLE PRESS PROCESS

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SUMMARY

Location of the resin and the use of slack mercerization with restretching were studied as a means of producing a cotton sewing thread with durable press properties while avoiding the excessive abrasion resistance loss that, in the past, has accompanied resin treatments on threads. The effects of resins of the DMEU, DMDHEU, and the triazine types were studied singly and in conjunction with slack mercerization with restretching. Tension mercerized threads treated with these resins were run in comparison tests.

Work of rupture and abrasion resistance cycles were plotted as an indicator of the degree of sewability. The graph showed that the slack mercerized thread which had been given a resin treatment (DMDHEU) and a top finish of polyethylene would withstand the sewing operations. Those treated threads which were not slack mercerized did not perform as well.

Staining techniques were used to show the location of the resin. Before the poison catalyst (aqueous ammonia) was applied, staining showed uniform penetration of the resins into the fibers. After application of the poison catalyst, the resins were found to be in or near the lumen.

CHAPTER I

INTRODUCTION

Statement of the Problem

The trend in recent years in garments and other textile products for direct human usage has been towards durable press materials. Items which are durable press are relatively easy to maintain. No ironing is required if the proper precautions are taken during the laundering operations. However, along with the good properties of durable press are some bad features. These are low abrasion resistance, low strength and puckered seams.

The textile industry has coped with these problems by utilizing synthetic fibers, mainly the polyester type. However, the resin that is applied to the textile material reacts only with the cellulosic component. Polyester possesses certain features which cause it to behave similarly to resin treated cotton, but polyester lacks the comfort afforded by cotton.

The abrasion resistance problem associated with durable press has been minimized by usage of polyester in the fabric.

Resin treated cotton threads break easily during the sewing operation. Pure synthetic threads or synthetic core threads pass through the needle eye easily but do not match the dimensional stability of the fabric, thus, causing seam pucker.

Furthermore, polyester has cut into the usage of cotton. Therefore any treatment that could produce durable press and be competitive physically and economically with polyester-cotton blends would be much welcomed by those who deal primarily with cotton.

As early as the 1950's attempts were made to produce resin treated cotton sewing threads which possessed properties similar to those of the resin treated fabrics. During this period of research, various chemicals were used on the thread which gave wash-wear or crease resistant properties on the fabric. However, all of the studies found that the loss of breaking strength and abrasion resistance which occurred when these chemicals were applied to cotton, and which could be tolerated in the fabric, could not be tolerated in the thread.

A single fiber might break in the fabric and no significant change in the fabric would be noticed, but in a sewing thread the breakage of a single fiber was extremely significant. The breakage of fiber in the sewing thread was due primarily to the vigorous passage through the various components of the sewing machine and into the fabric. The application of the resin to give the desired crease resistant finish or durable press finish was quite simple; however, the level of concentration that was allowable for non-breakage of the sewing thread was too low to impart the desired properties.

If untreated cotton thread was sewed into the treated fabric, massive seam pucker occurred. Thus, the necessity for a sewing thread which behaved identically to the fabric is apparent. The present solution consists of utilizing blends of synthetic polymers such as polyester or nylon and cotton or pure synthetic polymer. The synthetic polymer is quite stable after pressing and curing and will retain its dimensional stability.

The advent of durable press treatments has increased the demand for garments which are free of seam pucker and still retain the properties of cotton, such as comfort. Furthermore, the farmer would like to see cotton on a truly competitive basis with the synthetic materials.

Purpose

The objective of this research was to develop a system of applying resins such as triazine types, DMEU, and others (whether they be cross-linking or thermoplastic types) to cotton sewing thread with the intention of producing durable press qualities while maintaining sufficient abrasion resistance.

Organization and Approach

The organization of the problem was centered around three approaches: (1) a preliminary study of several treated threads; (2) a literature survey of resin treatments, slack mercerization and staining techniques; and (3) combination of any information gleaned from the first two into a feasibility study.

The preliminary study was based on work performed during contract research on the "Basic Physics of Seam Pucker" (1). The contract work was concerned with the usage of resin treated fabrics and threads in an effort to reduce seam pucker in commercially sewed, lightweight garments. All of the resin treated threads except one were unsatisfactory. The one exception was produced by techniques which are proprietary. The treated thread produced by the classified techniques possessed abrasion resistance nearly equal to that of its untreated version. The sewability was excellent as long as the speed of the sewing machine was kept below 4,000 RPM. (The machine was usually operated at full speed -- 5,200 RPM)

During the same contract work, slack mercerized threads were received from Southern Regional Research Laboratories (SRRL) of the United States Department of Agriculture in New Orleans, Louisiana. These threads showed a high increase in abrasion resistance (2) and work of rupture. An earlier study of the work of rupture and abrasion resistance of threads which had been mercerized under tension showed no change in the work of rupture but a decrease in the abrasion resistance (3). Since slack mercerization tends to increase the abrasion resistance of cotton sewing threads and resin treatments tend to reduce the abrasion resistance of cotton threads, the author decided to combine the treatments with hopes that the two treatments would neutralize each other.

A study of lubricants as a means of increasing the abrasion resistance was not undertaken. The literature (4, 5) showed in general that polyethylene emulsions tended to give marked increase in the abrasion resistance of threads and fabrics. For the duration of the work, a polyethylene softener was used as the only lubricant.

A literature survey of thread treatments proved to be fruitless. Conversations with the directors of research of two large thread manufacturing companies were of much value. These people indicated why the literature was void of material on the subject. Each company wanted a competitive edge on its competitors and their work had not been too successful.

Shippee and Gagliardi (6) showed that the abrasion resistance of materials treated by poison catalyst systems, as measured by the fiber toughness, was greatly improved over the conventional pad-dry-cure technique. The poison catalyst systems used in their study were thickened cellulose gum with sodium carbonate and thickened urea.

Slack mercerization was studied extensively at SRRL in New Orleans. Reed, Kullman, and Blanchard (7) found that slack mercerization and restretching to the original length before resin treatment lessened the loss of strength (25 percent versus 42 percent in the original thread). Murphy and Margavio (8) found much the same type of evidence. Again, in separate studies Sloan, Hoffman, Reeves and Cooper (9) and Reeves, Cooper, Sloan and Harper (10) studied the effects of slack mercerization and restretching prior to resin treatment with crosslinking agents and found that the reduction in strength was lessened by this pretreatment.

CHAPTER II

EQUIPMENT AND INSTRUMENTATION

Self-Abrader

During the preliminary examination the abrasion tests were made on a Walker Self-abrader furnished by the Coats and Clark Company Laboratory of Atlanta. However, a self-abrader was made which operated on the same principle as the Walker Self-abrader, except that the length of the region being tested on each specimen and the number of cycles per minute could be varied. The Walker Self-abrader had neither of these features. (See Figure 1.)

After the construction of the self-abrader, several test runs were made. The first was with a Dacron sewing thread, size 50/2. The number of cycles for the abrasive rupture was too high for good correlation. Also, the time involved for this one test was too long (three and one-half hours).

Fortisan samples were used to test the self-abrader in more realistic situations. Since Fortisan is a de-acetylated cellulose acetate, the tests correlated significantly with the cotton test thread. The Fortisan thread was coated with a silicone finish.

The tests were designed to show any positions that were producing extreme variations in the abrasion of the thread specimens.

The upper third of Table 1 shows the results of four runs on the tester before any adjustments were made. The middle section shows the results of four runs after polishing those positions which gave low

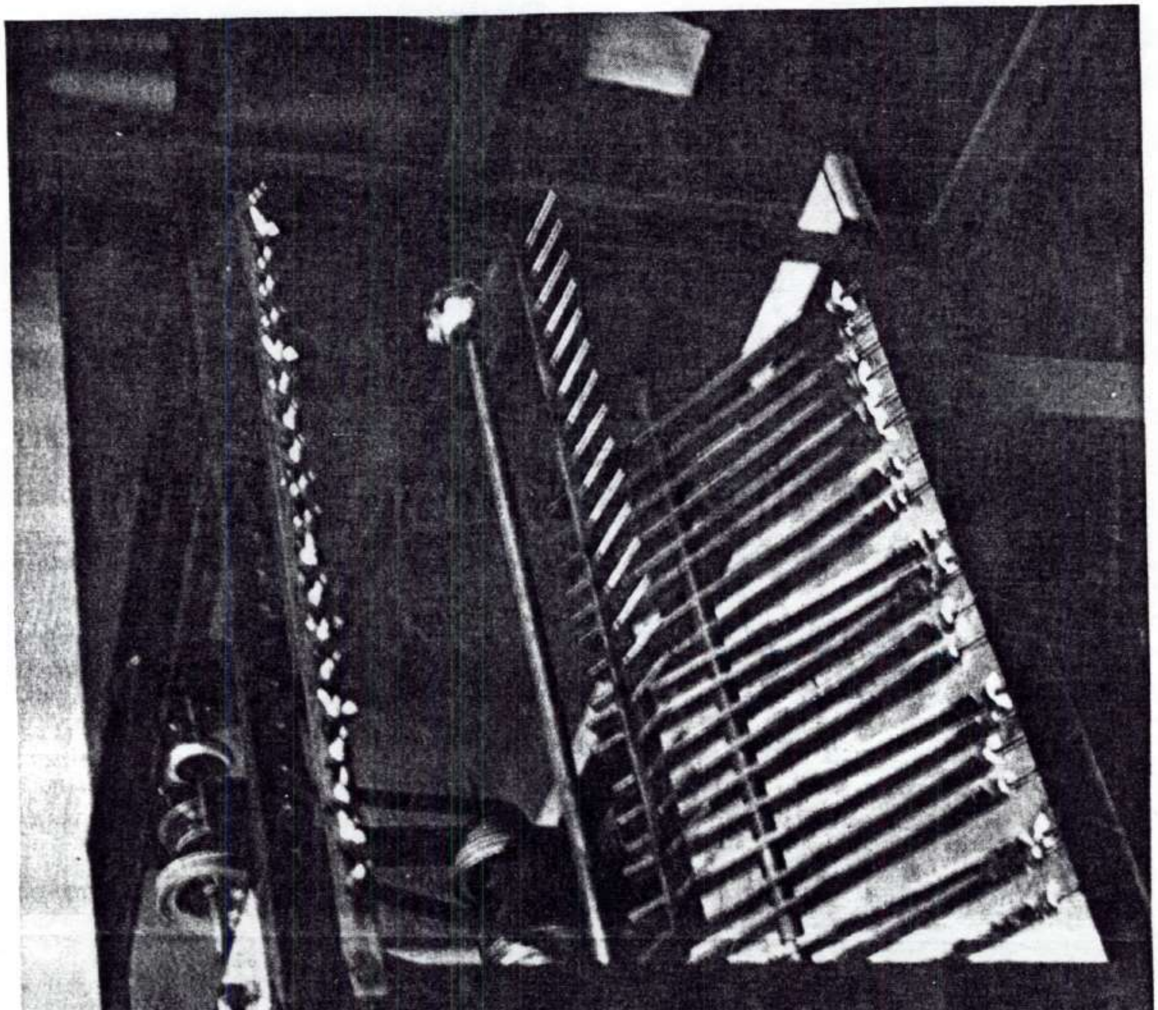

Figure 1. Self-Abrading Abrasion Tester

readings in the first sections. The lower third shows the results after a second polishing. (See Appendix, Table 1.)

Instron Tester

All breaking strength, work of rupture, and elongation tests were run on the Instron Tester, Model TT-C. The Instron is a servo-electronic type instrument. When a force is applied to the strain gage, a voltage change occurs and the change is recorded by a strip recorder. The breaking strength is recorded directly while the elongation is recorded by comparison of the rates of travel of the jaws and the strip recorder. The recorder is designed to stop when the sample breaks. In all tests for this work, the jaws were set to travel at the rate of 10 inches per minute. For simplicity the recorder paper speed was set at 10 inches per minute; thus, a one-to-one correspondence existed.

The work of rupture was recorded by utilizing an integrator attached to the circuitry of the Instron. This was the digital type manufactured by Hewlett Packard Company.

Atlab Finish Applicator

The third major piece of equipment needed for this work was the Atlab Finish Applicator manufactured by the Precision Instrument Company and designed by the Atlas Chemical Company, Inc. This instrument is designed to continuously apply finish to a yarn at any desired percentage of add-on. The Atlab Finish Applicator utilizes a motor driven syringe to supply the finish, with a tension device for the correct amount of tension and an internally heated dry can to dry the finished yarn after application of the finish.

A computer type counter is a feature of this instrument. The counter allows any length of run to be made with automatic shut down of the dry can. The dry can has two functions: (1) dry the finish on the yarn, and (2) pull the yarn past the point of application of the finish. A canted roller is used to space the yarns at any specified distance on the dry can (See Figure 2).

The finish is applied by passing the yarn through a continuously replenished drop of finish solution. The proper motor-syringe combination is found by first applying distilled water with various combinations until one combination maintains the drop of water.

The required concentration of finish was calculated using the following formula:

$$\text{grams/liter} = \frac{0.6 \times A \times W \times RPM}{F}$$

where: g/l = concentration of the finish in grams per liter

A = percent finish desired on the fiber

W = weight of yarn resulting from 1,000 revolutions of drying can

RPM = revolutions per minute of drying can = 17.6

F = feed rate of selected motor-syringe combination

The above description gives the technique for finding the proper feed rate (motor-syringe combination). To facilitate the work, a table of feed rates was established and is given in the following section.

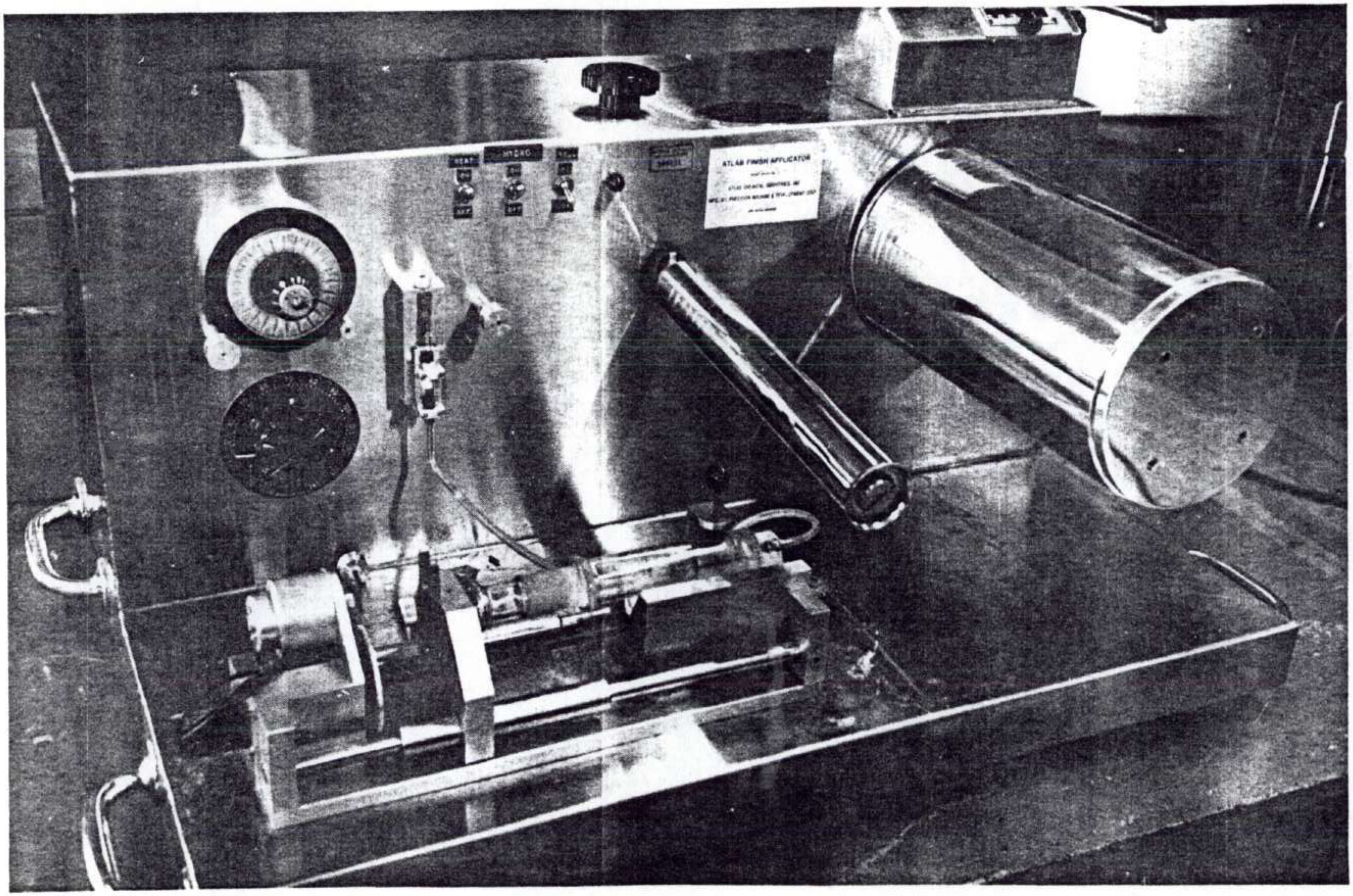

Figure 2. Atlab Finish Applicator and Winder

Calculation of the Flow Rates of Syringes for the Atlab Finish Applicator

The instruction manual for the Atlab Finish Applicator furnished information on the flow rates of the 30 cc. syringe which was furnished with the instrument. To determine the flow rates of replacement syringes which were of different capacities and had plungers of different diameters the following procedure was used:

The flow of any given volume of water in a syringe may be determined by the empirical formula,

$$\text{Flow} = (\text{area of plunger}) \times (\text{velocity of plunger})$$

Since the velocity of the plunger is directly proportional to the speed of the force applied (in this case, the syringe motor) and the area of the plunger face is equal to its diameter squared, multiplied by the value of pi; the flow is then given by the expression:

$$\text{Flow} = (\text{speed of driving motor}) \times \pi d^2$$

Then assuming there is no change in the speed of the driving motor in any one case:

$$\text{Flow} = kd^2$$

When a different motor is used, a new constant k must be found. From the data given in the instruction manual for the Atlab Finish Applicator for the Multifit 300 cc. syringe, the value of k for each motor may be calculated. Tables 2 and 3 show the data for each motor and syringe combination and the k values for each motor.

Table 2. Calculation Motor Constant for Atlab Finish Applicator

Syringe Capacity (cc)	Diameter (inches)	Diameter Squared
30 (Multifit)	0.8931	0.7976
20 "	0.7710	0.5944
10 "	0.5775	0.3351
5 "	0.4615	0.2130
50 (Substitute)	1.0938	1.1964
30 "	0.8337	0.6951

RPM	Constant
10	0.0341
9	0.0378
8	0.0424
5	0.0682
3	0.1156

Table 3. Calculation of Flow Rates*

for Syringe-Motor Combinations

Syringe Capacity (cc)	Motor Speed (RPM) 10	9	8	5	3
30 (Multifit)	23.4	21.1	18.8	11.7	6.9
20 "	17.4	15.7	14.0	8.7	5.1
10 "	9.8	8.8	7.9	4.9	2.9
5 "	6.2	5.6	5.0	3.1	1.8
50 (Substitute)	35.1	31.6	28.2	17.5	10.3
30 "	20.4	18.4	16.4	10.2	6.0

* Flow rates are cc/hr.

Curing Oven

Initially, curing was attempted on a Callaway Slasher and a homemade infrared heated copper tube. These methods of curing were not successful. A muffle furnace was modified by removing the ceramic plug in the back and the window in the front of the furnace. Also, a variable transformer was placed in series with the muffle furnace's potentiometer; this gave the temperature control that was required for curing. A thermometer was placed in the back port after the furnace had been allowed to come to equilibrium.

The furnace proved to be an excellent curing oven. The test thread was mounted in a tensioning device on the right side of the muffle furnace and with the winder and its tensioning device placed on the left side of the muffle furnace (See Figure 3).

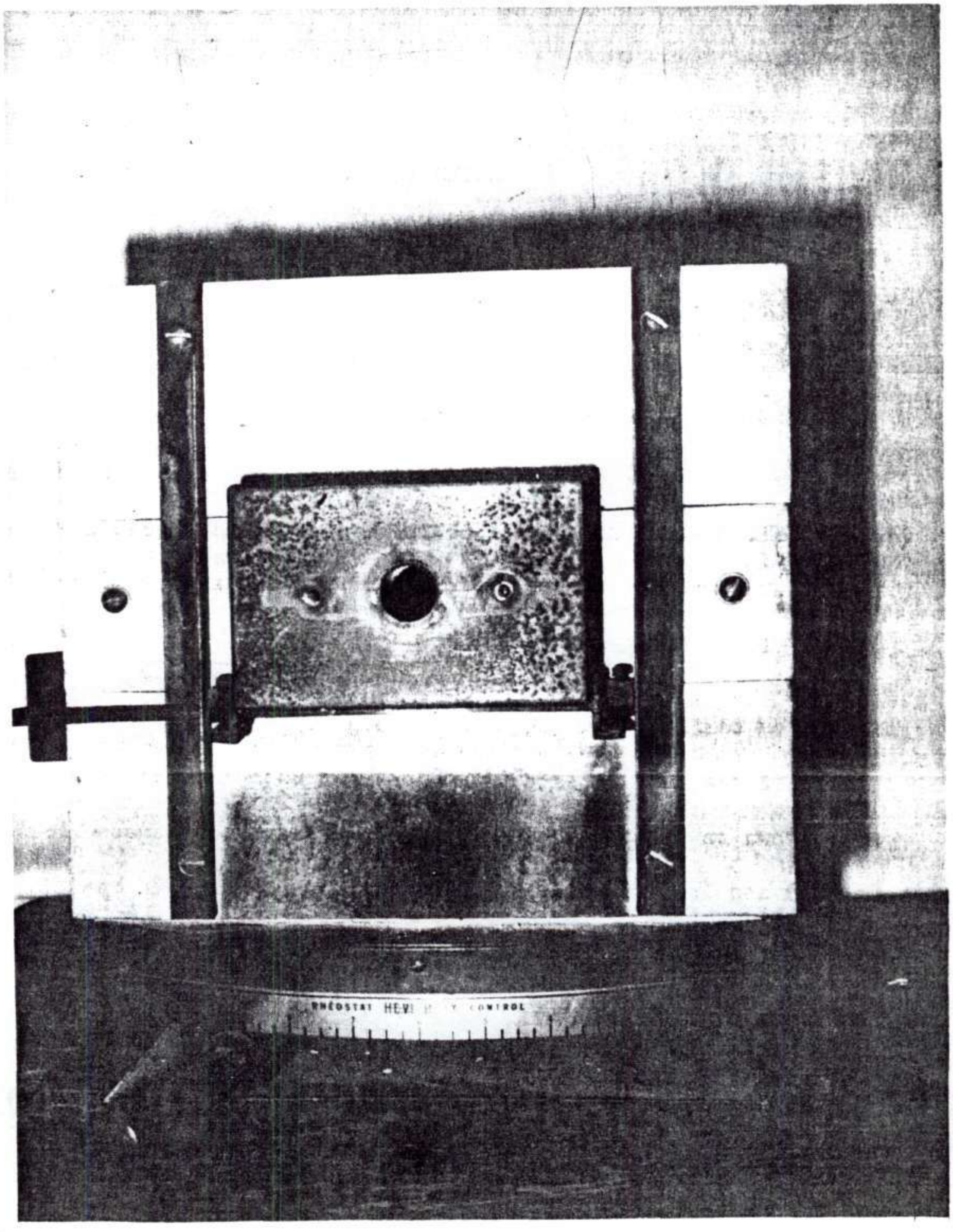

Figure 3. Continuous Curing Oven (Modified Muffle Furnace)

CHAPTER III

EXPERIMENTAL

Chemicals and Materials

Bleached, American Cotton threads of 70/2 count in both soft and tension mercerized versions were given to the author by Coats and Clark Company. The resins (dimethlolethyleneurea, DMEU; dimethyloldihydroxyethyleneurea, DMDHEU; triazine; and a modified urea-formaldehyde type) were obtained from the Seydel-Woolley Company of Atlanta, Georgia and the Sun Chemical Company of New Jersey.

Preparation of Materials and Equipment

A Leesona winder (single bobbin type) was modified to operate at variable speeds in the range of 0-200 RPM. (These speeds were required because the Atlab Finish Applicator operated at two speeds; 17.6 RPM and 35.6 RPM, depending on the requirements of the rate of application of finish to the threads). A weighted dancer was located between the dry can of the Atlab Finish Applicator and the winder to maintain uniform tension upon the thread.

Trial runs were made on the Atlab Finish Applicator using distilled water and the soft untreated thread to determine the proper feed rate.

In the initial phases of the study the Leesona winder was used to wind the treated thread but was discarded because of the variations in the winding performance. The winder was too sensitive to changes in the line voltage in the laboratory. As a result a new winder was built which was not as easily affected by voltage changes.

Resin Treatments

The technical information that accompanied Sun Chemical Company's resins recommended that of the resins requested by the author only the Permafresh Reactant 183 would give the properties of durable press. The others were not designed to produce durable press properties.

As a result of these recommendations, only Permafresh Reactant 183 and Permafresh 424 were used in the main experimental program.

Seydell Woolley's Seycoset was used for the initial tests because a larger quantity was available. These initial tests consisted of determining the concentration of resin necessary to get a good stain that would be easily seen under the microscope.

Sun Chemical Company's X-4 catalyst was used on all test runs with both the DMEU resin (Seycoset) and DMDHEU resin (Permafresh Reactant 183). The catalyst was specifically recommended for ethylene-urea type resins. Also, Sun Chemical Company's softener, Mykon SF, was used on the untreated threads to provide controls for the sewability tests and on the final treated threads that were used in the sewability tests.

Application Techniques

As mentioned earlier the Atlab Finish Applicator was used to apply the resin, catalysts, and the softener. This instrument has been used by Wakelyn (11) to apply spin finishes to polyacrylonitrile fibers. In Wakelyn's study and this study, the instrument proved to be quite uniform in application of the chemicals once the proper flow rate was found.

The dry can temperature was set at 180° F. by using a variable transformer which was built into the instrument. The surface temperature was checked by fastening a thermometer to the dry can.

In the initial runs with the Atlab Finish Applicator a commercial winder was used to collect the treated thread, but due to the inertia of the winder frequent breaks were encountered. A new winder was built and the tension variation checked. The tension control was excellent with the new winder. Breakage of the threads occurred only when the winder speed was set too high.

Tension control was extremely important when running the slack mercerized thread. In producing the slack mercerized thread 90 percent restretching had been given the thread to obtain the maximum thread characteristics. If the winder speed was too high, the other 10 percent would be recovered and cancel most of the benefits of the slack mercerization process. Tension control was maintained by setting the winder on a separate table approximately two feet from the table on which the Atlab Finish Applicator was located and allowing the thread to pass through a dancer. The dancer could traverse a distance of 18 inches before the tension changed significantly (See Figure 4).

Three problems appeared during this work. The glass syringe is held in position by a rubber-tipped screw set near the center of

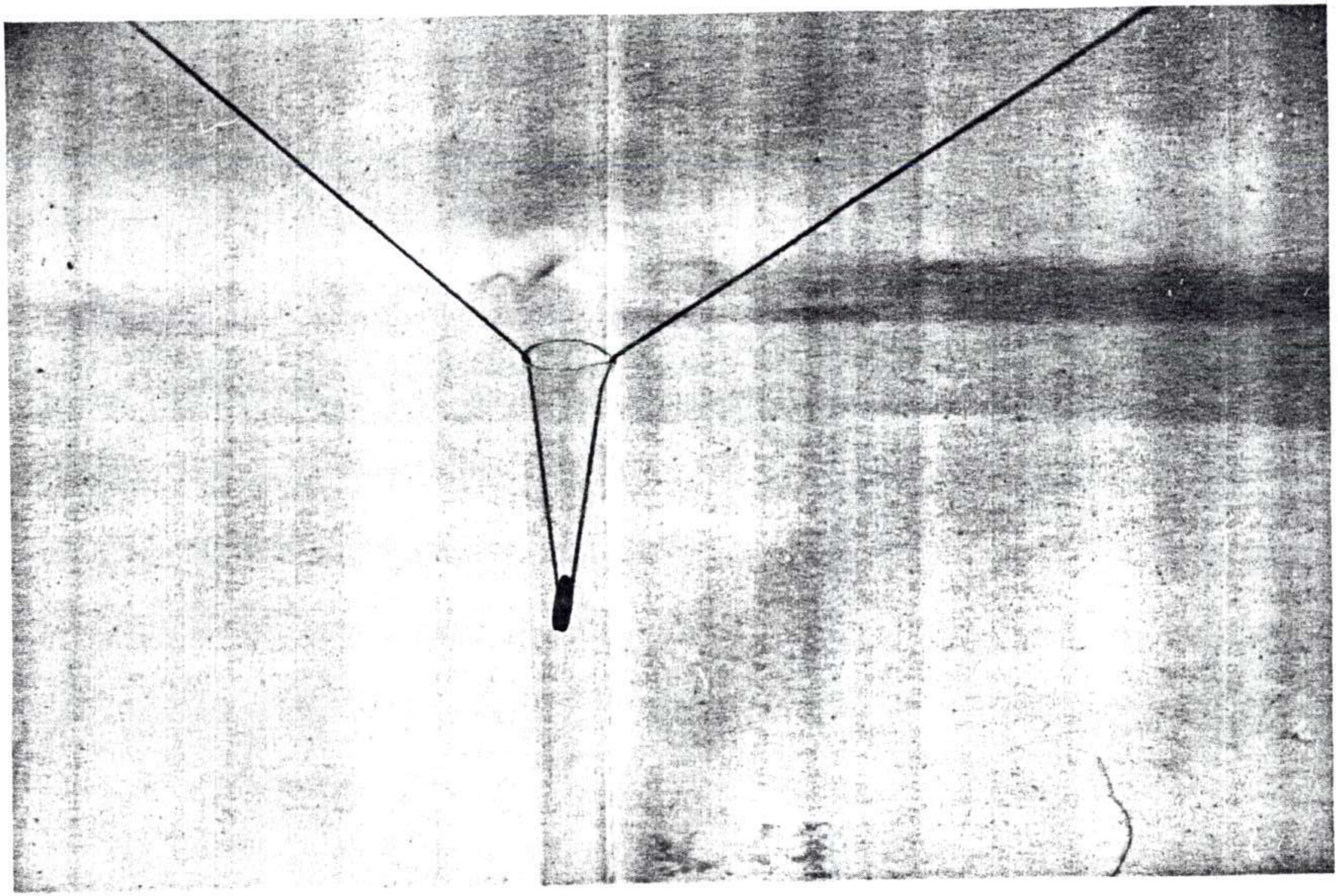

Figure 4. Weighted Rider Located Between the Atlab Finish Applicator and the Winder.

the syringe. If too much pressure was exerted by the screw, the syringe would become out-of-round and the plunger would bind. When this happened, the motor would break the collar of the syringe by pushing the whole apparatus forward until the collar contacted the mounting block. (Usually the syringe collar was placed against the block at the first of the operation by the operator). After making contact with the block, the pressure increased until the glass collar broke.

This problem was solved by not using the holding screw and placing a plywood plate in front of the syringe. This allowed the force applied by the motor to move parallel to the syringe and motor shaft while no force was applied perpendicular to the axis of drive.

The second problem was associated with the motor-syringe combination. The motor was not connected to the counter. When the counter shut the dry can off, the motor of the syringe drive continued to operate and eventually reached the end of the syringe barrel, causing the syringe to break.

The third problem associated with the Atlab Finish Applicator was the dry can circuitry. The dry can was heated by an electrical heater inside the dry can. To supply electricity to the heater, two slip rings were placed on one end of the dry can to press against the appropriate roller brushes which are connected to the power supply. When these roller brushes had been operated for a sufficient length of time (usually four to six hours), the pressure decreased and contact with the slip rings was broken causing a decrease in the temperature of the dry can. Furthermore, these roller brushes have stuck on occasion and had to be replaced. For future work by others, the author suggests a simple brush system.

Upon completion of the winder and the necessary trial runs to test the winder, 10 percent solutions of the DMEU, DMDHEU, and triazine resins were made with magnesium (II) chloride as the catalyst in all tests. Each resin was applied to each of the soft and tension mercerized threads using the Atlab Finish Applicator.

A one percent owf (on weight of fiber) solution of a polyethylene type softener was made and applied in the same manner. As a comparison 100 feet of the soft thread were padded with a 10 percent owf solution of DMDHEU on the Butterworth Laboratory Padder according to commercial techniques of applying durable press resins to cotton goods. Approximately one-half was cured on the Callaway Slasher and the rest was left uncured.

After applying the various resins to the threads, samples were taken before and after curing for determination of the location of the resin. An acid dye, 0.25 percent owf solution of Anthraquinone Blue BN (C.I. Acid Blue 45), was used in determining the location of the resin. To avoid the necessity of preparing a new solution and to reduce the time involved in making the dye solutions, enough dye solution was prepared to treat 100 grams of resin-treated thread. The pH was adjusted to six by the addition of glacial acetic acid and checked with a pH meter after each portion of acid was added.

In each case, small specimens of each treated and untreated thread were selected to reduce the handling of large specimens. Also, only an extremely small portion of test thread was required for the cross-sectioning work.

A check with the microscope showed that the concentration of resin was not high enough for an accurate analysis of the location of the resin after staining. Several cross-sections showed one out of approximately 50 fibers with resin. The one fiber was not uniformly stained. No explanation was available for the uneven application. especially on the one fiber. Several of the other test threads showed the same results.

A 25 percent owf solution of a melamine derivative resin and magnesium chloride catalyst was prepared and a soft thread was run on the Atlab Finish Applicator using this solution. One portion was left uncured and the other was cured using the modified muffle oven.

The uncured portion was tested for all of the physical properties and with the Anthraquinone Blue BN dye. The earlier procedure of allowing each sample to stay in the dye bath for a 24 hour period was followed with the one exception - a two inch specimen was removed after four hours. At the end of the 24 hour period, the remainder was removed and rinsed with distilled water. There was no difference between the two threads with respect to the time in the bath.

A viscous solution of cellulose gum and water (15 grams of cellulose gum - 99.5 percent carboxymethylcellulose by Hercules Powder Company - in 500 ml. of distilled water) was used as a means of providing a carrier for the poison catalyst and to prevent the complete removal of all of the resin, especially in the central portions of the fiber. To this solution 0.53 grams of sodium carbonate was added to give a 0.01 M basic solution as the poison catalyst to be used to remove the melamine resin on the surface and outermost fringes of the cotton fiber.

This solution of poison catalyst was poured into a funnel through which the treated thread passed. The thread was then passed into the muffle furnace and wound onto a second tube by the winder. At the tip of the funnel small beads of poison catalyst were noted. These beads did not dry completely upon passage through the curing oven. They disappeared only when a damp paper towel was held against the thread. Then the thread dried quite well in the oven and the curing appeared to be quite normal.

After the application of the poison catalyst, the thread was wound into skein form and scoured lightly in hot, soapy water for five minutes and then rinsed twice in cold distilled water. The "hand" appeared to be quite rough even after scouring in the above described manner. A specimen was placed in the dye bath for four hours to determine the extent of removal of resin from the surface of the thread and/or the fibers. After removal of the specimen and thorough rinsing in distilled water, an examination under the microscope showed no significant removal of the resin.

Due to the harsh "hand" and insignificant removal of the resin by the cellulose gum method, a second technique for applying the poison catalyst was developed using aqueous ammonia as the poison catalyst and glass tubing as the housing. This method did not decrease the "hand" and greatly reduced the activity of the resin reaction.

The apparatus was placed between the oven and the thread supply which was to be treated. Initially, an aspirator was connected to the glass tubing to force the ammonia fumes through the tubing. However, the leakage of air through the thread inlet was too high and the system failed to operate properly. The pump was attached in such a way that it would force air through the solution of ammonium hydroxide causing the ammonia to escape into the glass tubing through which the thread passed.

The thread was fed directly into the muffle furnace which was operating at 325° F. Upon emerging from the furnace the thread was wound onto a tube. Then small portions were removed, washed lightly with warm soapy water and rinsed with distilled water. These specimens were then stained and examined under the microscope.

Following the visual examination under the microscope all of the stained test specimens were photographed at 110X.

Physical Tests

After completion of all resin treatments, tests were made of the various physical properties. These were work of rupture, breaking strength, elongation, and abrasion resistance. The first three physical properties were determined on the Instron Tester. The abrasion resistance tests were performed on the self-abrader and on the Union Special sewing machine (Model 63400-A) which was designed to sew light weight garments such as shirts and dresses. The sewing tests were designed to test the ability of the resin treated threads to pass through the rigorous sewing operation without failure. Table 5 shows the results of the breaking strength, elongation, work of rupture, and abrasion resistance while Table 6 indicates the probability of good sewing behavior.

A graph of the work of rupture versus abrasion resistance was made and divided into the respective sewability zones, based on the data from Tables 5 and 6.

Table 4. Description of Treated Threads

Specimen Number	Description
1	Soft Control
2	Tension Mercerized Control
3	Slack Mercerized Control
4	Soft, 10% DMDHEU, pad method, uncured
5	Soft, 10% DMDHEU, pad method cured
6	Soft, 25% Triazine uncured
7	Soft, 25% Triazine cured, Cellulose Gum System
8	Soft, 25% Triazine cured, Ammonia System
9	Soft, 2% Mykon SF
10	Slack Mercerized and Restretched, 10% DMDHEU uncured
11	Slack Mercerized and Restretched, 10% DMDHEU, Ammonia System
12	Slack Mercerized and Restretched, 10% DMEU uncured
13	Slack Mercerized and Restretched, 2% Mykon SF
14	Tension Mercerized, 10% DMEU uncured
15	Soft, 25% DMDHEU uncured, continuous w/o catalyst
16	Soft, 10% DMDHEU cured
17	Soft, 25% DMDHEU uncured, continuous w/catalyst
18	Soft, 10% DMEU uncured
19	Slack Mercerized and Restretched, 10% DMDHEU Ammonia System, 2% Mykon SF

Table 5. Average Physical Properties* of Test Threads

Specimen Number	Breaking Strength	Elongation	Work of Rupture	Abrasion Resistance
1	1.80	5.7	58.8	11.8
2	2.11	4.5	56.9	10.0
3	2.24	9.5	73.1	15.3
4	1.63	4.8	41.4	7.5
5	1.64	4.4	39.8	7.4
6	1.31	4.8	31.2	3.1
7	1.56	5.5	46.5	5.8
8	1.50	4.9	56.4	8.1
9	2.17	4.7	51.6	13.6
10	1.89	7.5	68.3	11.6
11	1.79	7.2	66.0	12.9
12	1.94	6.7	62.4	10.1
13	2.14	9.3	71.3	24.4
14	2.06	4.1	44.0	8.1
15	1.50	4.9	39.4	6.3
16	1.60	5.6	46.9	8.4
17	1.75	5.0	44.0	7.6
18	1.79	6.2	51.5	8.7
19	1.81	7.3	69.2	14.2

* Breaking strength is measured in pounds; elongation, percentage; work of rupture (to be multiplied by 10^{-2}), in.- lbs; abrasion resistance, cycles.

Table 6. Sewability of Test Threads

Specimen Number	Sewability
1	Good
2	Fair
3	Excellent
9	Good
10	Good
11	Good
12	Fair
13	Excellent
14	(Did not sew)
16	(Did not sew)
18	(Did not sew)
19	Excellent

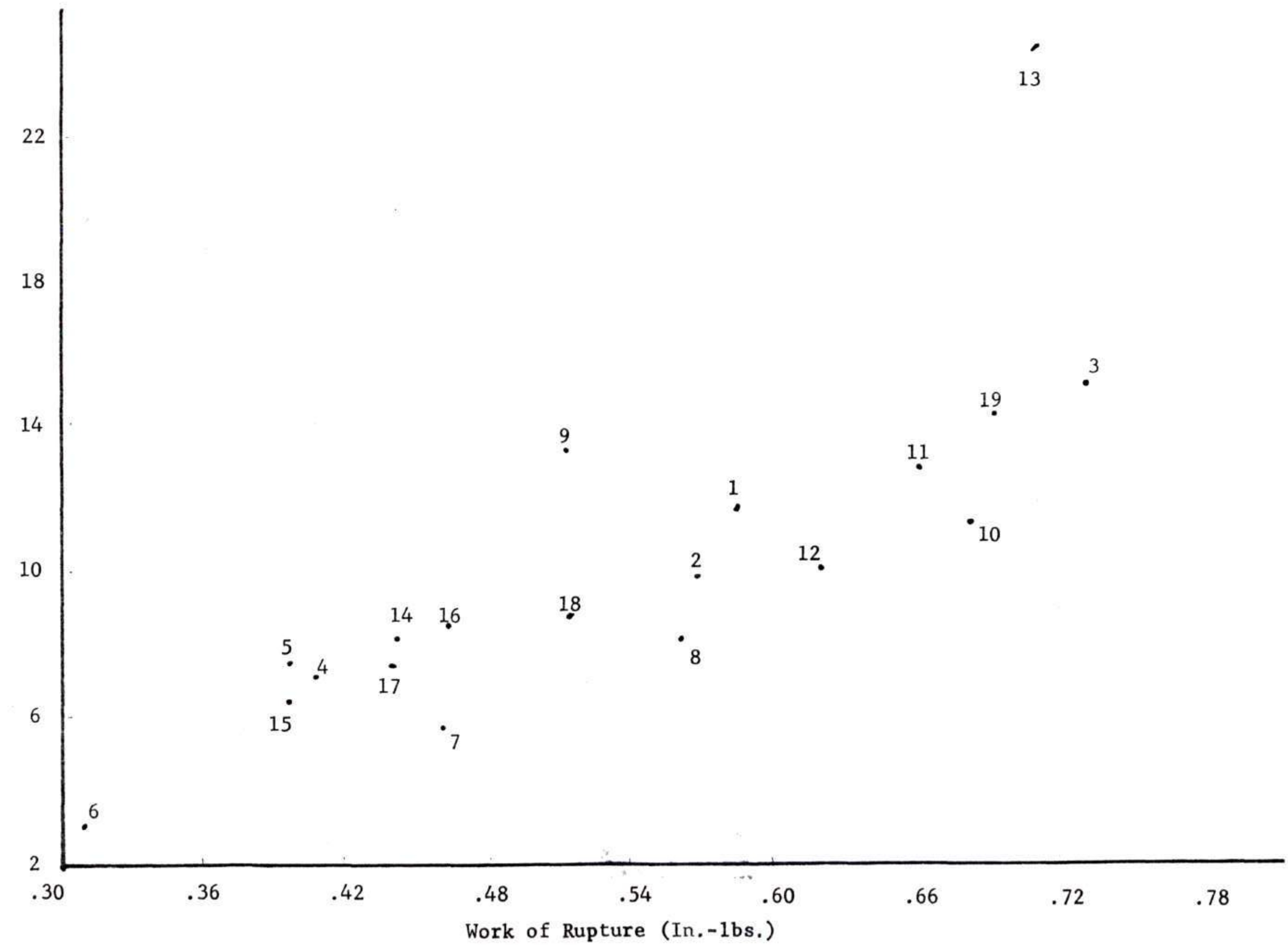

Figure 5. Graph of Work of Rupture Versus Abrasion Resistance (Including Sewability Zones)

CHAPTER IV

DISCUSSION OF RESULTS

General

The preliminary study indicated that the location of the resin was a very important factor. However, the location of the resin alone was not as significant as location of the resin when combined with slack mercerization. Those threads with the resin located in the lumen of the fiber possessed higher abrasion resistances than those produced by the pad-dry-cure method. Furthermore, slack mercerization causes a large increase in the abrasion resistance of the untreated thread; however, it does not give durable press properties. Together, the two treatments gave a treated thread with good abrasion resistance and durability.

The resin treatment caused a considerable loss in the abrasion resistance of the slack mercerized yarn; however, this loss nearly equaled the gain in the abrasion resistance of untreated thread when subjected to the slack mercerization process. The decrease in the work of rupture (when compared to the untreated thread) is not significant.

Breaking strength and elongation properties were duly recorded but because they were not utilized in determining the sewability of the threads, they were not evaluated.

Analysis of Test Threads

The differences found in the physical properties of tensioned mercerized thread and slack mercerized thread are illustrated in Figure 5. Tension mercerization reduces the abrasion resistance while slack mercerization increases the abrasion resistance. When resin (DMEU, DMDHEU, or triazine) was applied to the three control threads, the abrasion resistance of the three types was reduced and the sewability decreased as a function of the loss of abrasion resistance and work of rupture. However, the degree of reduction was not the same for all three thread types.

Generally, these threads which were treated with DMDHEU did not lose as much abrasion resistance as those threads treated with DMEU or triazine. Those threads which were treated at the 25 percent level can not be expected to show high abrasion resistance or work of rupture. These threads were treated at the high concentration for staining purposes only.

The slack mercerized threads had the highest abrasion resistance and work of rupture. Also, sewability was generally better for these threads than that of the soft or tension mercerized threads. This domination alone shows the significance of the slack mercerization process. When the polyethylene softener was applied to the slack mercerized control thread, the abrasion resistance increased sharply.

An evaluation of the uncured and cured pad-dry-cure method of application of resin shows the same type of performance that the work under contract with SRRL showed; i.e., the curing of the DMDHEU tends to reduce the work of rupture with no significant change in the abrasion resistance.

When the pad-dry-cure method is compared with the continuous process (specimens 4 and 18 respectively), the continuous process of application shows greater work of rupture and abrasion resistance. The concentration of resin was the same in both cases.

The cellulose gum method of applying the poison catalyst did not give as good results as the ammonia system. The cellulose gum is difficult to remove completely. The ammonia system does not contribute any additional material that will affect the physical properties. There is a danger with the ammonia system that the ammonia will completely penetrate the fiber and cause total deactivation of the resin.

After all of the various treatments to determine the effects of resin and poison catalyst systems on soft, tension mercerized, and slack mercerized threads, the DMDHEU resin and the polyethylene softener were applied. The locus of the soft control is near the locus of the treated thread, indicating a slight change in the physical properties of the original thread while the thread is now dimensionally stable (See Figure 5).

Sewability Tests

Not all of the test threads were sewed into fabric during the sewability tests. Only specimens 1, 2, 3, 9, 10, 11, 12, 13, 14, 16, 18, and 19 were used in these tests. Specimens 14, 16, and 18 failed to sew at any speed. Specimens 2 and 12 sewed when the machine speed was reduced. The remainder sewed well at full speed (5,200 RPM).

Cross-sections of the Test Threads

Staining of the test threads revealed that the continuous process of applying the resin is much more uniform than the batch method. The heavier concentrations of resin on some of the test threads showed a very uniform application. The cured threads were stained uniformly.

The poison catalyst (the ammonia system) effectively prevented the resin near the surface of the thread from reacting with the cotton. The resin was located only in the central section of the fibers. (See Figures 6,7, and 8.)

The poison catalyst has the opposite effect that the acid catalyst does. The acid catalyst promotes the formation of corr-linkages with the cellulose while the poison catalyst has the tendency to prevent such linkages. The unreacted resin may be removed by lightly washing.

The washing and rinsing operation also removes any of the acid catalyst; thus, the formation of covalent linkages is unlikely during any subsequent high temperature operations such as ironing if any of the unreacted resin is still present.

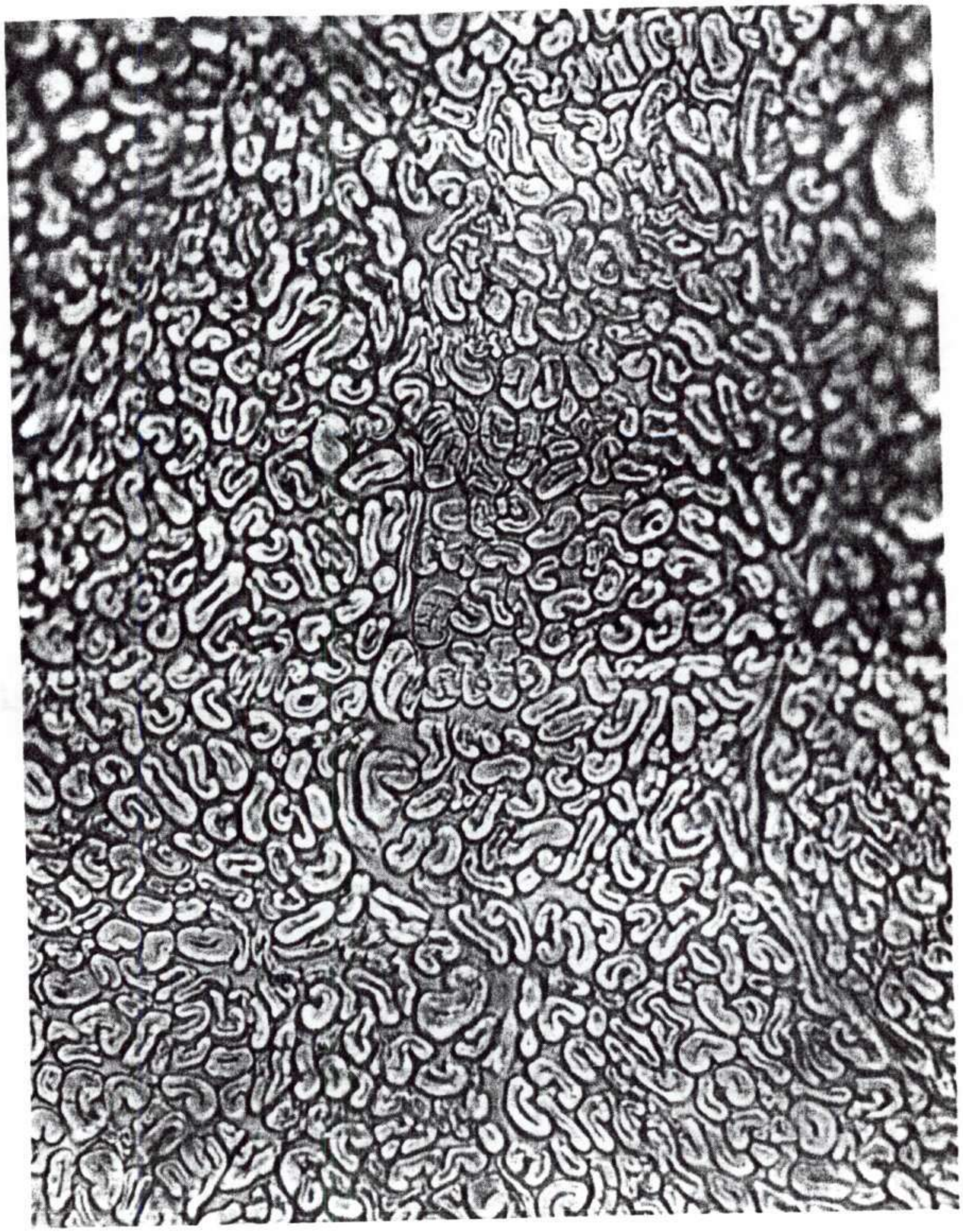

Figure 6. Cross-section of Untreated Soft Thread

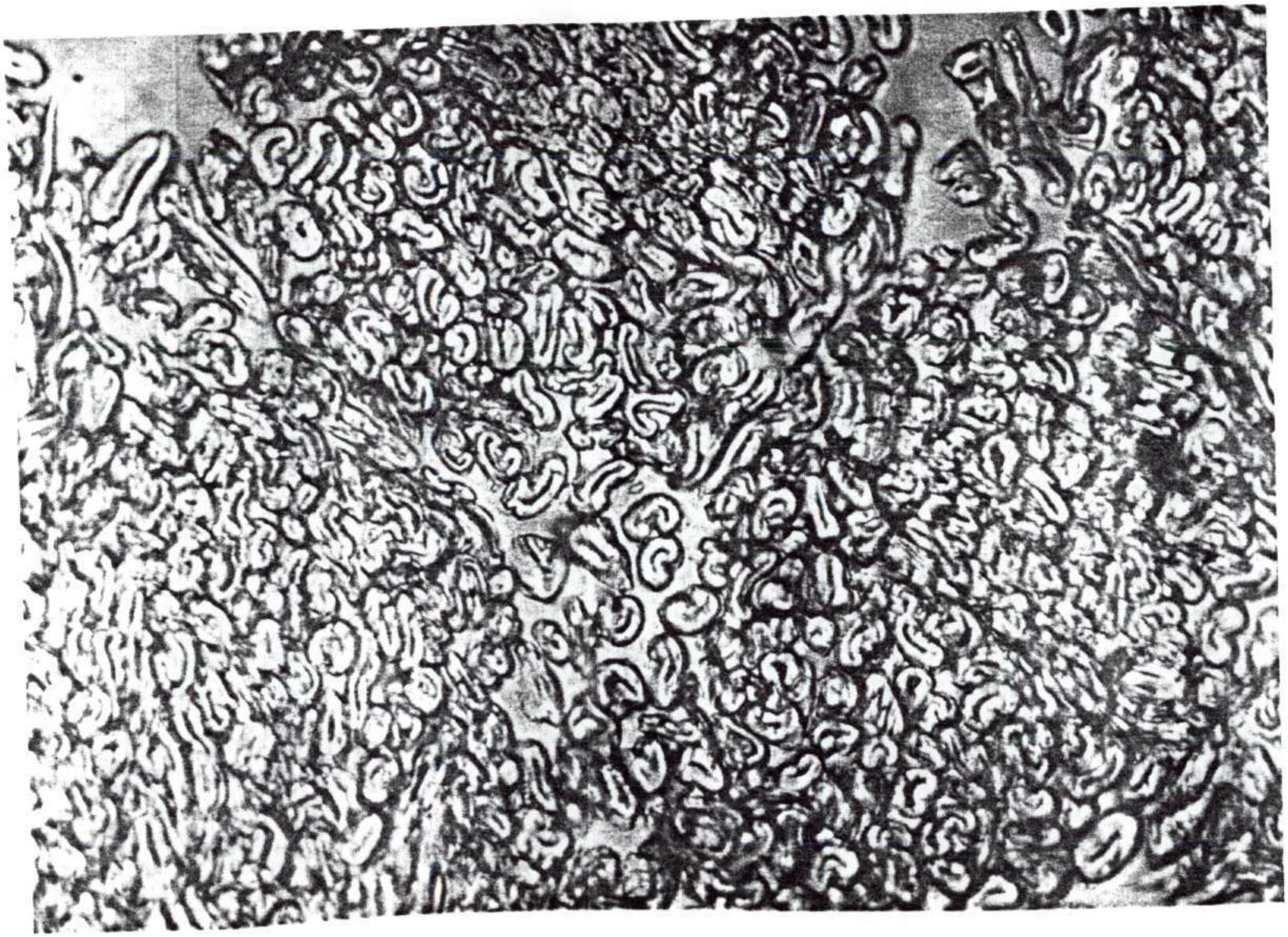

Figure 7. Cross-section of DMDHEU Treated Thread Before Selective Poisoning (Soft Thread)

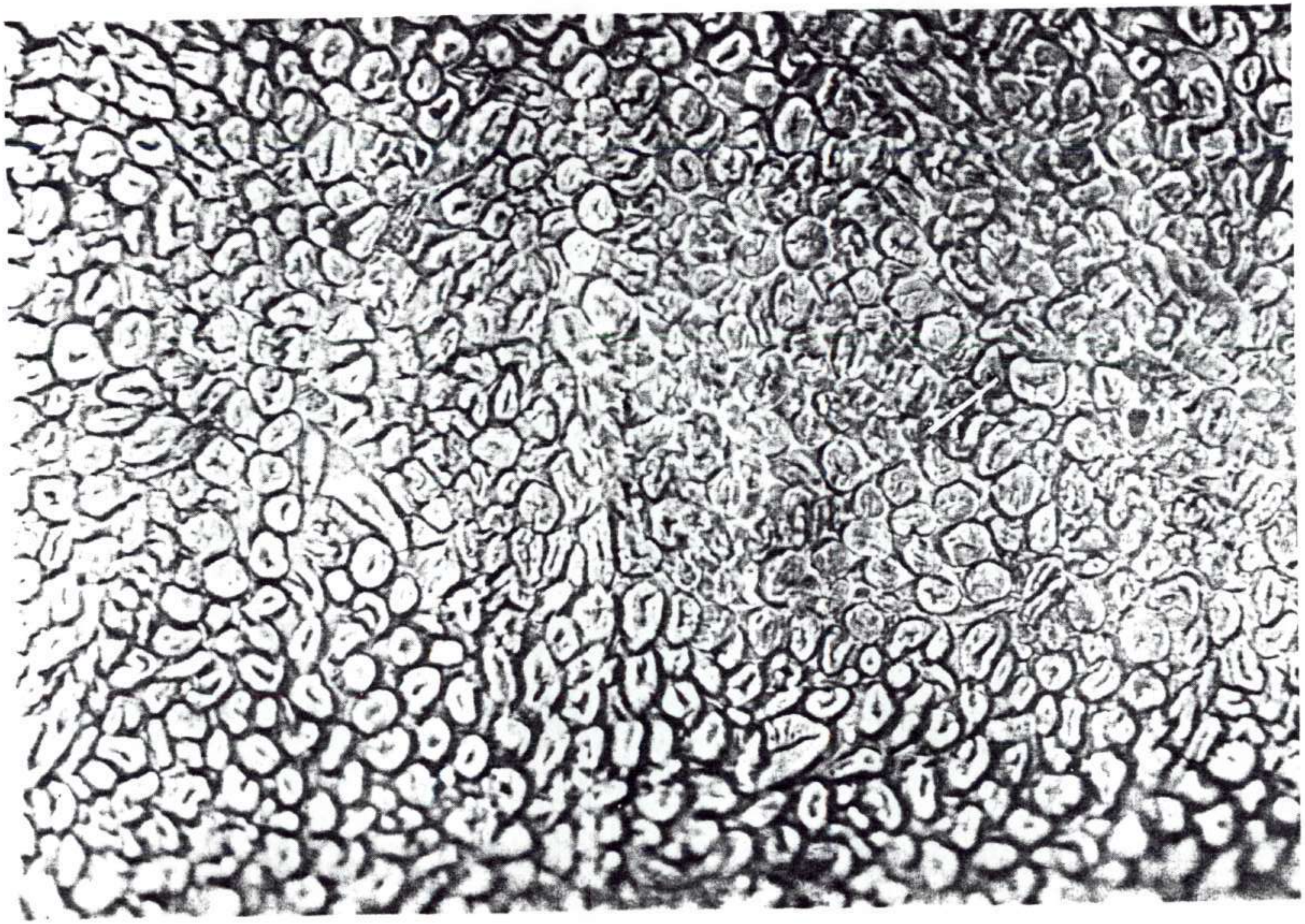

Figure 8. Cross-section of DMDHEU Treated Thread After Application of Ammonia as Poison Catalyst (Slack Mercerized Thread)

CHAPTER V

CONCLUSIONS

The following conclusions were drawn from the work:

(1) The location of the resin plays a very important role in the abrasion resistance of cellulosic materials which have been treated with chemicals for the durable press process. If the resin is located on or near the surface of the treated material, then the servicable life of the material is greatly shortened. If the resin is located within the lumen of the cotton fiber, the life of the material is nearly equal that of the untreated fiber.

(2) Slack mercerization with 90 percent restretching adds sufficient abrasion resistance to a cotton thread so that the thread possesses nearly all of its original abrasion resistance after resin treatment of the type used by the author.

(3) The combination of slack mercerization and centralization of the resin within the lumen produce a cotton sewing thread which will pass the rigorous sewing operations of the sewing machine and still possess durable press type properties.

CHAPTER VI

RECOMMENDATIONS

The author has only two recommendations and they are as follows:

(1) That the technique developed by the author be applied to all cotton fabrics in an attempt to produce 100 percent cotton fabrics which would be competitive with polyester-cotton blends used to make durable press garments.

(2) A new resin of the type that will react with cellulose on one end of the resin while the other end easily forms a homopolymer with itself or a similar type resin. This would, in the author's opinion, increase the durable press properties of cotton by filling the lumen of cotton with the homopolymer while attaching the resin to the walls of the lumen.

APPENDIX

Table 1. Adjustment of the Abrasion Tester With Two-Ply Fortisan Thread.

Treatment	Position Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
w/o	9	12	12	13	10	22	22	13	5	13	13	14	16	16	10	17	12	15	7	6
polishing	6	11	12	12	14	10	13	13	6	14	12	11	15	10	13	16	12	13	4	5
	9	16	14	12	10	9	13	14	6	12	16	13	17	14	15	14	12	14	x	5
	10	x	12	13	12	13	14	9	7	15	19	13	19	14	10	13	13	15	8	7
Totals	34	39	50	50	46	43	51	49	24	54	60	51	65	54	48	58	49	57	19	23
Averages	9	13	13	13	12	11	13	12	6	14	15	13	16	14	12	15	12	14	6	6
First	13	14	14	15	12	11	12	12	9	14	18	12	14	16	17	14	13	12	12	6
polish	14	10	18	16	14	14	11	12	10	13	10	14	19	12	13	16	16	14	10	6
	12	10	14	16	15	10	12	15	8	11	12	11	17	15	13	9	14	15	10	5
	12	13	13	16	11	12	17	13	10	15	9	11	17	14	11	15	15	16	10	6
Totals	51	47	59	63	52	47	52	52	37	52	49	48	70	57	54	54	58	57	42	23
Averages	13	12	15	16	13	12	13	13	9	13	12	12	18	14	14	14	15	14	11	6
Second	12	11	14	15	10	17	11	15	12	11	18	17	14	13	11	15	12	13	14	13
polish	13	13	20	17	12	16	11	12	16	15	15	13	16	15	13	16	13	x	16	16
	14	14	15	15	x	13	13	12	11	12	13	14	16	18	13	18	13	16	14	15
	13	13	15	18	12	14	13	14	17	16	15	17	15	15	15	16	16	18	13	13
Totals	52	51	64	65	34	60	48	53	56	54	61	61	61	61	52	65	54	47	57	57
Averages	13	13	16	16	11	15	12	13	14	14	15	15	15	15	13	16	14	12	14	14

Table 7. Physical Properties of Soft Control Threads.

Specimen No.	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	64	2.00	5.5	12
2	56	1.85	5.2	11
3	62	1.87	5.8	10
4	53	1.67	5.7	14
5	51	1.68	5.0	12
6	41	1.50	4.8	13
7	70	1.97	6.3	12
8	65	1.85	6.7	14
9	69	1.96	6.0	10
10	54	1.67	5.7	13
Total	585.0	18.02	56.7	121
Average	59	1.80	5.7	12
Standard Deviation	4.2	0.178	0.174	2.1
Percent CV	7.1	9.9	3.1	17.5

Table 8. Physical Properties of Tension Mercerized Control Threads

Specimen No.	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	67	2.24	5.3	9
2	58	2.21	3.8	11
3	51	1.97	4.0	9
4	60	2.23	4.1	12
5	54	2.02	4.0	11
6	57	2.22	3.9	10
7	45	1.88	3.7	11
8	67	2.37	4.4	10
9	46	2.00	3.6	10
10	64	2.36	4.0	10
Total	569	21.50	40.8	103
Average	57	2.15	4.1	10
Standard Deviation	6.7	0.16	0.46	2.6
Percent CV	11.8	7.5	11.2	26.0

Table 9. Physical Properties of Slack Mercerized Control Threads

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	80	2.40	9.0	18
2	72	2.15	9.3	16
3	75	2.32	9.4	15
4	69	2.19	9.5	15
5	69	2.12	9.6	16
6	74	2.35	9.7	14
7	74	2.27	9.5	14
8	69	2.26	9.6	16
9	74	2.18	9.5	15
10	75	2.20	9.4	14
Total	731	22.44	94.5	153
Average	73	2.24	9.5	15
Standard Deviation	5.1	0.16	0.18	3.2
Percent CV	7.0	7.1	1.9	21.3

Table 10. Physical Properties of

Soft, 10 percent DMDHEU Pad Method, Uncured Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	43	1.66	4.8	8
2	42	1.83	5.6	8
3	35	1.47	4.7	6
4	45	1.70	5.1	7
5	43	1.64	5.0	9
6	35	1.44	4.2	7
7	45	1.70	4.7	8
8	44	1.68	4.5	7
9	43	1.63	4.6	6
10	39	1.51	4.5	9
Total	414	16.26	47.7	75
Average	41	1.63	4.8	8
Standard Deviation	3.6	0.10	0.25	1.6
Percent CV	8.8	7.2	5.3	20.0

Table 11. Physical Properties of

Soft, 10 percent DMDHEU, Pad Method, Cured Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	40	1.55	4.7	9
2	33	1.48	4.0	7
3	38	1.56	4.2	7
4	36	1.58	4.1	8
5	39	1.62	4.4	9
6	44	1.75	4.4	6
7	40	1.64	4.4	8
8	48	1.87	4.7	8
9	43	1.75	4.5	6
10	37	1.63	4.7	7
Total	398	16.43	44.1	74
Average	40	1.64	4.4	7
Standard Deviation	4.1	0.15	0.24	1.6
Percent CV	10.3	9.1	4.7	20.0

Table 12. Physical Properties of

Soft, 25 percent Triazine, Uncured Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	29	1.28	4.9	2
2	28	1.32	5.0	1
3	32	1.31	4.6	5
4	34	1.33	4.7	4
5	34	1.34	4.7	4
6	31	1.32	4.8	5
7	30	1.30	4.9	2
8	33	1.34	4.8	3
9	31	1.31	4.7	3
10	30	1.29	4.7	2
Total	312	13.14	47.8	31
Average	31	1.31	4.8	3
Standard Deviation	4.0	0.14	0.18	1.3
Percent CV	13.0	10.7	3.8	42.9

Table 13. Physical Properties of Soft, 25 percent Triazine Cured, Cellulose Gum Removal System Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	47	1.50	5.8	5
2	47	1.57	5.9	5
3	52	1.65	5.8	7
4	38	1.36	5.1	6
5	39	1.56	6.1	7
6	51	1.62	5.6	6
7	47	1.65	5.6	6
8	47	1.63	5.2	5
9	46	1.54	5.4	6
10	41	1.48	4.9	7
Total	465	15.56	55.4	58
Average	47	1.56	5.5	6
Standard Deviation	4.0	0.089	1.15	0.95
Percent CV	8.5	5.7	20.9	15.8

Table 14. Physical Properties of Soft,

25 percent Triazine Cured, Ammonia System Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	60	1.55	4.9	8
2	60	1.56	4.8	7
3	65	1.67	3.5	8
4	58	1.63	4.9	8
5	60	1.64	4.9	10
6	60	1.52	5.0	7
7	57	1.52	4.6	7
8	52	1.55	5.1	6
9	62	1.40	4.8	9
10	50	1.66	4.8	8
Total	584	15.77	47.1	78
Average	58	1.58	4.9	8
Standard Deviation	4.2	0.06	0.49	1.1
Percent CV	7.2	3.8	10.3	13.8

Table 15. Physical Properties of Soft, 2 percent Mykon SF Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	52	2.22	4.4	14
2	48	2.01	4.5	13
3	52	2.19	4.8	14
4	51	2.37	4.8	14
5	58	2.34	4.9	16
6	45	2.09	4.7	14
7	55	2.25	4.9	13
8	49	2.17	4.5	12
9	48	2.00	4.7	14
10	48	2.06	4.8	12
Total	516	21.70	47.0	136
Average	52	2.17	4.7	14
Standard Deviation	4.8	0.13	0.17	1.8
Percent CV	9.2	6.00	3.6	13.1

Table 16. Physical Properties of Slack Mercerized and Restretched, 10 percent DMDHEU Uncured Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	65	1.79	7.5	12
2	79	1.99	8.0	13
3	58	1.75	6.7	11
4	61	1.85	6.8	12
5	64	1.95	6.8	13
6	74	1.95	8.3	10
7	66	1.88	7.6	10
8	65	1.82	7.4	13
9	75	1.88	7.9	10
10	76	2.00	7.9	12
Total	683	18.86	74.9	116
Average	68	1.89	7.5	12
Standard Deviation	6.8	0.084	0.53	1.6
Percent CV	10.0	4.4	7.1	13.3

Table 17. Physical Properties of Slack Mercerized and Restretched, 10 percent DMDHEU, Ammonia System Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	67	1.76	7.3	14
2	75	1.87	7.9	13
3	68	1.72	7.9	15
4	72	1.78	8.0	12
5	63	1.61	7.8	12
6	69	1.72	7.7	12
7	65	1.62	7.9	14
8	65	1.87	6.9	12
9	62	1.93	5.8	13
10	54	2.03	5.0	12
Total	660	17.91	72.2	129
Average	55	1.79	7.2	13
Standard Deviation	5.5	0.15	1.12	1.1
Percent CV	8.3	8.4	15.6	8.5

Table 18. Physical Properties of Slack Mercerized and Restretched, 10 percent DMEU Uncured Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	50	1.67	6.0	11
2	64	2.03	7.6	12
3	72	2.04	7.2	8
4	70	2.05	7.1	9
5	62	1.95	6.2	11
6	63	1.94	6.7	12
7	66	1.97	6.9	9
8	63	1.98	6.8	10
9	64	1.97	6.3	10
10	50	1.75	5.8	9
Total	624	19.35	66.6	101
Average	62	1.94	6.7	10
Standard Deviation	6.9	0.18	0.54	1.7
Percent CV	11.1	9.3	8.17	17.0

Table 19. Physical Properties of Slack Mercerized and Restretched, 2 percent Mykon SF Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	70	2.10	9.8	25
2	72	2.14	9.5	26
3	76	2.19	9.6	24
4	71	2.20	9.1	22
5	68	2.19	9.3	25
6	69	2.11	9.2	23
7	70	2.12	9.4	24
8	73	2.11	9.0	25
9	74	2.15	9.2	24
10	70	2.13	9.3	26
Total	713	21.44	93.4	244
Average	71	2.14	9.3	24
Standard Deviation	6.9	0.14	0.89	4.6
Percent CV	9.7	6.50	9.60	19.2

Table 20. Physical Properties of Tension

Mercerized, 10 percent DMEU Uncured Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	44	2.10	4.1	9
2	40	1.97	3.8	8
3	49	2.20	4.3	6
4	47	2.12	4.2	8
5	46	2.15	4.0	7
6	43	2.04	4.2	7
7	47	2.11	4.3	9
8	36	1.92	3.7	10
9	48	2.08	4.3	8
10	40	1.88	4.0	9
Total	440	20.57	40.9	81
Average	44	2.06	4.1	8
Standard Deviation	4.0	0.10	0.2	0.9
Percent CV	9.1	4.90	4.9	11.3

Table 21. Physical Properties of Soft, 25 percent

DMDHEU Uncured, continuous without catalyst

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	44	1.68	4.8	8
2	50	1.83	5.0	6
3	39	1.50	4.8	5
4	45	1.62	5.7	8
5	47	1.66	5.3	4
6	37	1.47	5.3	7
7	30	1.23	4.5	6
8	29	1.25	4.2	5
9	36	1.36	5.0	8
10	37	1.42	4.8	6
Total	394	15.02	49.4	63
Average	39	1.50	4.9	6
Standard Deviation	6.6	0.2	0.41	1.9
Percent CV	16.9	13.3	8.37	31.7

Table 22. Physical Properties of

Soft, 10 percent DMDHEU Cured Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	54	1.72	5.9	9
2	49	1.63	5.6	9
3	39	1.65	5.7	8
4	47	1.57	5.1	7
5	46	1.54	5.5	8
6	54	1.75	5.8	8
7	42	1.51	5.3	10
8	51	1.62	5.8	8
9	45	1.54	5.7	8
10	42	1.50	5.2	9
Total	469	16.03	55.6	84
Average	47	1.60	5.6	8
Standard Deviation	4.9	0.16	0.26	0.8
Percent CV	10.4	10.00	4.60	10.0

Table 23. Physical Properties of

Soft, 25 percent DMDHEU Uncured, Continuous with Catalyst Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	36	1.58	4.8	7
2	48	1.83	5.2	8
3	37	1.58	4.4	6
4	47	1.78	5.0	10
5	46	1.75	5.2	7
6	45	1.82	4.9	6
7	42	1.78	5.0	9
8	51	1.90	5.2	6
9	45	1.75	5.0	10
10	43	1.70	5.0	7
Total	440	17.47	49.7	76
Average	44	1.75	5.0	8
Standard Deviation	4.5	0.10	0.75	1.5
Percent CV	10.2	5.7	15.1	18.8

Table 24. Physical Properties of

Soft, 10 percent DMEU Uncured Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	55	1.87	6.0	7
2	53	1.86	5.8	8
3	58	1.93	6.1	8
4	62	1.97	6.6	10
5	53	1.90	5.8	9
6	49	1.75	5.9	9
7	47	1.67	5.7	8
8	50	1.77	6.2	9
9	41	1.58	6.7	9
10	47	1.63	6.7	8
Total	515	17.93	61.5	87
Average	52	1.79	6.2	9
Standard Deviation	5.7	0.08	0.37	1.1
Percent CV	11.0	4.70	6.00	12.2

Table 25. Physical Properties of Slack Mercerized and Restretched, 10 percent DMDHEU Ammonia System, 2 percent Mykon SF Threads.

Specimen Number	Work of Rupture	Breaking Strength	Elongation	Abrasion Resistance
1	73	1.89	7.9	13
2	67	1.75	7.7	16
3	70	1.82	7.1	13
4	72	1.65	7.1	14
5	68	1.88	7.6	12
6	65	1.59	6.9	13
7	68	1.90	7.1	17
8	71	1.93	7.3	16
9	66	1.91	7.4	15
10	70	1.80	6.8	13
Total	690	18.12	72.9	142
Average	69	1.81	7.3	14
Standard Deviation	2.5	0.44	0.35	2.9
Percent CV	3.6	24.40	4.80	20.7

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